

DEPARTMENT OF THE INTERIOR
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HISTORICAL CHANGES OF SHORELINE AND WETLAND AT ELEVEN MAJOR DELTAS IN THE PUGET SOUND REGION, WASHINGTON

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INTRODUCTION

River-mouth deltas and associated wetlands have a historical and continuing importance to human activities. Deltas in the Puget Sound region attracted early development because they were fish-rich, near water, and contained relatively large tracts of unforested land. These characteristics fostered the conversion to farmlands, port facilities, and centers of commerce and industry. Delta areas in the Puget Sound region have undergone considerable change, both natural and man-related, since their first occupancy by non-Indian settlers. Until recent years, little thought was given to the environmental values of wetlands and the impacts of man's activities there. As the effects of these activities on the natural qualities of wetlands have become more widely known and better appreciated, information documenting past changes has been needed by planners, environmental groups, local agencies, and others concerned with the development and well-being of the delta areas. In response to this interest and need, comparisons of old and new maps delineating historical shoreline and wetland changes have been compiled for 11 major river deltas in the Puget Sound region, as shown on the accompanying maps. These maps document (1) shoreline changes, both natural and man-induced, since early non-Indian settlement, (2) loss of wetland habitat, and (3) patterns of land-use changes on delta lands. Also presented are discussions of some overall planning considerations related to shoreline and wetland changes. In addition, this report may serve as a basis for future studies of geologic and hydrologic conditions and processes in the delta areas.

The areas studied are shown in figure 1 and listed below:
Sheet 2. Nooksack River and Bellingham Bay, and Lummi River and Lummi Bay
Sheet 3. Samish River and Samish Bay
Sheet 4. Snohomish River and Possession Sound
Sheet 5. Skagit River and Skagit Bay
Sheet 6. Stillaguamish River and Port Susan
Sheet 7. Duwamish River and Elliott Bay
Sheet 8. Puyallup River and Commencement Bay
Sheet 9. Nisqually River and Nisqually Reach
Sheet 10. Skokomish River and Annas Bay
Sheet 11. Dungeness River and Dungeness Bay

The approach used, in general, was to locate and obtain the oldest authoritative maps of the areas and then to compare those historical maps with the most current topographic maps. The historical map data were then carefully transferred, by optical projection and manual plotting, to film copies of modern maps of 1:24,000 scale. No attempt was made to show the progression of change in the delta areas and, therefore, intermediate-age maps are not shown in this series. However, for some map compilations, intermediate-age source materials were used to help verify or evaluate the overall changes. These maps are one of a series of products being prepared by the Puget Sound Earth Sciences Applications Project to present basic information and interpretations of an environmental nature to assist land-use planning, resource development, and environmental management in the Puget Sound region. The work was begun at the request of U.S. Fish and Wildlife Service and Justice Department, and received financial support by the Bureau of Indian Affairs.

The authors express their appreciation to: Dr. Howard Droker, historian, for contributing information on the early development of tidelands in the Puget Sound region; Richard Meyer, National Oceanic and Atmospheric Administration (NOAA), Seattle, for arranging use of microfilm files; Cmdr. Glen Schofield, NOAA, Seattle, for technical advice; and Capt. Wesley Hull, NOAA, Rockville, Maryland, for investigating old records files.

SOURCE MAPS

The sources of historical maps showing river deltas and estuarine wetlands include the following:

1. National Oceanic and Atmospheric Administration (NOAA) archives, Rockville, Maryland (early U.S. Coast and Geodetic Survey maps).
2. National Cartographic Information Center, Reston, Virginia (early U.S. Geological Survey maps).
3. U.S. Army Corp of Engineers, Records Section, Seattle.
4. National Archives (old aerial photographs).
5. University of Washington, Library Map Center.
6. University of Washington, Library Northwest Collections.
7. King County Courthouse, Records Section (old land plans).
8. The U.S. Coast and Geodetic Survey (C&GS) topographic maps were generally the best sources of historical data because of their early, area-wide coverage, suitable scale, detail of mapping which shows features that persist to the present, and the identification of land grids on the survey sheets. Topographic copies, mostly at a scale of 1:20,000, of the original C&GS topographic sheets from 1854 to 1899 were obtained from the Rockville, Md., archives.

The name, date, original scale of the topographic and hydrographic surveys, and other information on each source map are listed in table 1.

DATA-TRANSFER PROCEDURES

Every effort was made to accurately transfer data from the historical maps to provide the best fit on the modern maps. Clear photographic copies of the oldest available source maps were obtained and by optical projection were reduced to the base-map scale. The historical shorelines, low-water lines, wetland limits, and selected map-pattern data from the maps were projected to modern base maps by use of a Bausch and Lomb model ZT4-H zoom transfer scope (ZTS). This instrument optically superimposes two separate images (source map and base map), and allows the viewer to match the scales and adjust for some types of linear discrepancy (if any) between the source and base maps and to trace one image on the other. The data were transferred by manual tracing onto copies of 1:24,000 (in one case 1:62,500)-scale USGS topographic maps. The modern topographic maps range in date of compilation from 1952 to 1973.

FACTORS AFFECTING ACCURACY

The nature of the source maps, judgments of individual compilers, and problems of data transfer all limit the absolute accuracy of the historical data shown. These factors are described below and in the descriptions of procedures on the individual map sheets.

*This symbol is used in the report as a identification purposes and does not imply endorsement by the U.S. Geological Survey.

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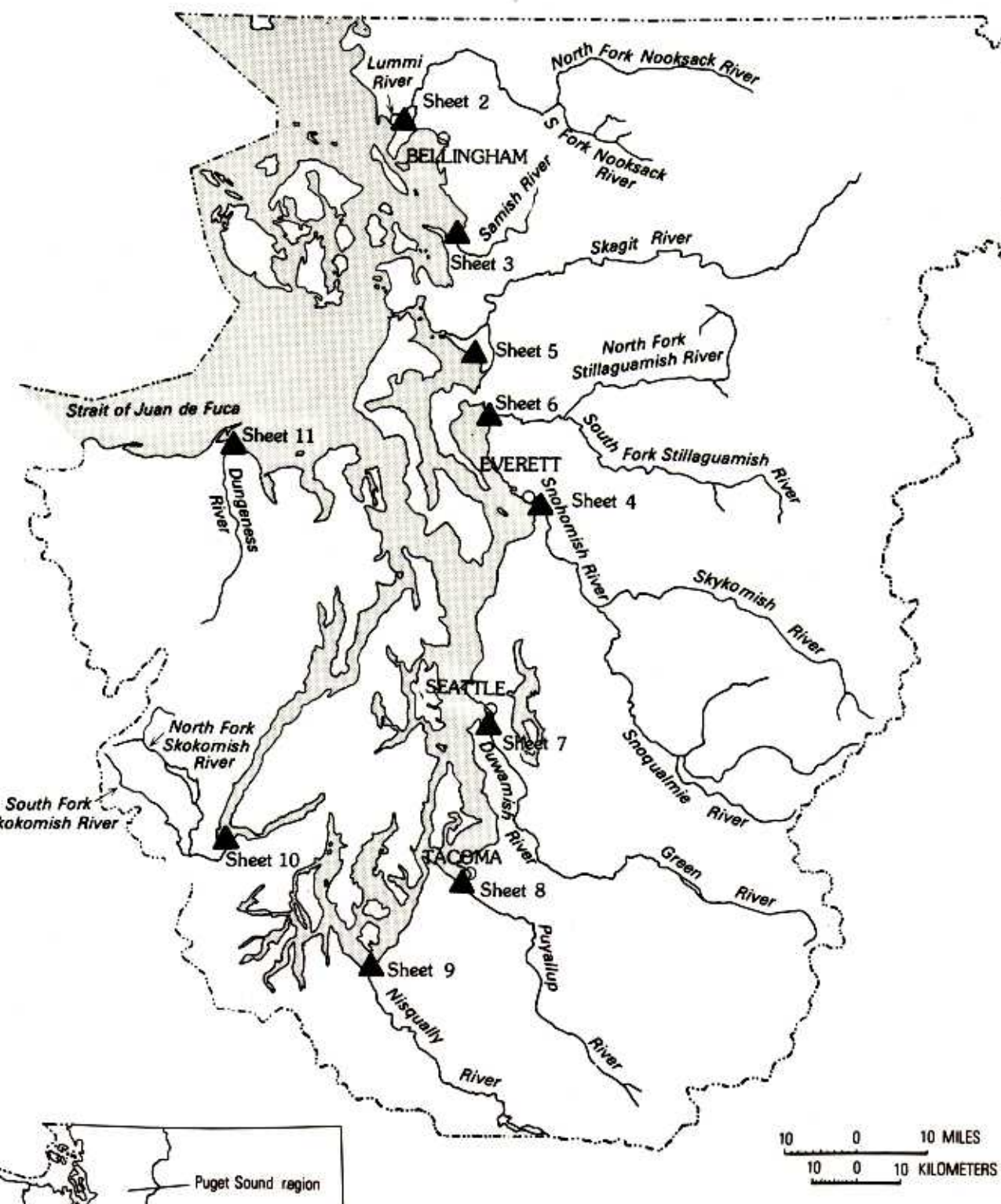


FIGURE 1—MAP OF PUGET SOUND REGION SHOWING
LOCATION OF SELECTED MAJOR RIVER-MOUTH DELTAS
(BLACK TRIANGLES)

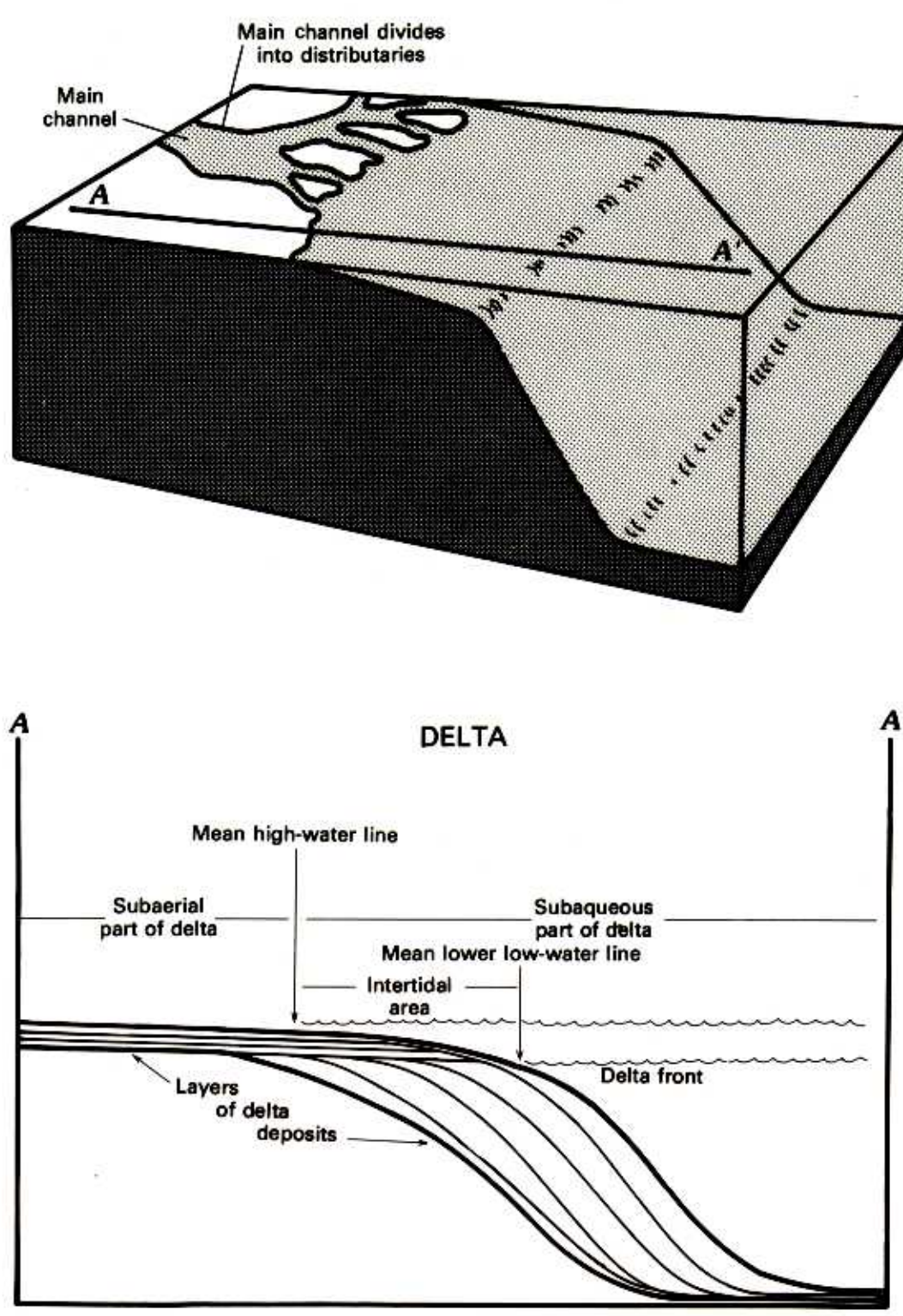


FIGURE 2—SCHEMATIC THREE-DIMENSIONAL AND
CROSS-SECTIONAL VIEWS OF A TYPICAL
RIVER-MOUTH DELTA

General Accuracy of the Early Surveys
The earliest maps of the region's coastline on a scale large enough to have sufficient detail for quantitative study are those made by the C&GS (Shalowitz, 1964, p. 79). They represent the best evidence available of the condition of the coastline 80 to 125 years ago. However, the survey work, though outstanding for its period, was not as accurate as is possible with modern mapping practices. For example, the early surveys were done by plane-table methods rather than the aerial photographic and photogrammetric methods available today. In plane-table surveys, the surveyor plotted the map data in the field on drawing-board sheets and measured distances and distances to selected features of the terrain using a telescopic alidade and stadia rod. The shoreline between the surveyed sites was sketched free-hand by the topographer. From these early survey sheets, there is no way to determine which points along the shoreline represent actual surveyed sites. Different topographers also used their discretion about details to be omitted or included on the maps.

In summary, as stated by Shalowitz (1964, p. 81), the degree of accuracy of the early surveys depends on many factors, among which are the purpose of the survey, the scale and date of the survey, the standards for survey work then in use, the importance of the area surveyed, and the ability and care of the topographer.

Land Grid
The modern USGS topographic maps and most of the early topographic surveys used a polyconic projection for the transfer of the meridians and parallels of the curved earth's surface to a flat map (Shalowitz, 1964, p. 136 and 141). However, the horizontal data, which determine the geographic positioning of meridians and parallels on the surface of the earth to a common reference point, have changed since the early topographic surveys were completed. Practically all recent surveys in the United States are based on the North American 1927 Datum. The majority of C&GS maps used as source materials show different historical land grids including that of the North American 1927 Datum, which was added to the maps by the C&GS after 1927.

Analytical and Interpretive Limitations
In using the early maps, it was important to determine the specifications and objectives of topographers in mapping of shorelines, marshes, and intertidal areas as well as characteristics of features represented by symbols or patterns used on the early maps. The most authoritative source for this information is Shalowitz (1964). Some analytical and interpretive limitations to the use of the early maps are discussed below.

Delineation of Shoreline and Wetland
The shoreline (line dividing land from water) shown on modern topographic maps represents the approximate line of mean high-water. Likewise, according to Shalowitz (1964, p. 174), beginning with the earliest surveys, it was the intention of topographers to delineate, as nearly as possible but without recourse to leveling, the line of mean high-water as the shoreline. In the field, the mean high-water line was interpreted by the surveyor from the appearance of the beach or by reference to predicted tides (Shalowitz, 1964, p. 189). Thus, a map compilation showing historical and modern shorelines should provide a common reference for the shoreline from which to evaluate changes in shoreline or wetland margins. Although the above premise is generally correct, it does not represent complete consistency, because the exact location of the high-water line is tidal-influenced marsh is often difficult to identify (Shalowitz, 1964, p. 177). For such areas the shoreline shown on the map may not always be the mean high-water line.

The upper, landward edge of marsh is often more difficult to determine than the seaward edge. Shalowitz (1964, p. 181), in discussing early surveys, indicated that, in general, the landward edge of marsh areas has always been interpreted as the dividing line between the marsh and upland, and not as representing any particular tidal elevation; generally it may be considered to be the limit of penetration of the highest tides. The early maps do not necessarily show the full landward extent of the marsh areas because the mapping may have stopped short of some inland portions.

Low-Water Line
The maps for eight of the eleven major deltas show a low-water line delineating the seaward edge of the intertidal wetland. The low-water line, in the context of plane-table surveys, is the topographer's estimate of the line representing a vertical datum defined by a phase of the tide, and is used as a reference plane for depths in the sea. The mean lower low-water line is the zero depth or datum from which water depths are measured and represents the low-water line of the early topographic surveys in the Puget Sound region (Shalowitz, 1964, p. 185).

Map Symbols
In the early period of topographic surveys, complete consistency in the use of symbols to represent various shore and land features reportedly was never attained due to the lack of standard symbols, and differing preferences of topographers. In order to facilitate comparison with modern conditions, the authors interpreted the original map symbols representing various features (for example, wetland, grassland, forested upland, shoreline, and dikes) to make them consistent for all the present map compilations. Also, the forested-uplands symbol on these compilations has been limited to a narrow band, rather than showing the entire landward extent as portrayed on the source maps. Otherwise, the limits of historical patterns as they are shown here represent the limits of mapping during the original surveys. The individual map explanations indicate symbols used to represent the historical map data and the corresponding modern symbols shown on the base map. Because there is no pattern for forested areas included on the base maps, the present-day extent of the forested upland is not shown and no distinction can be made between marsh and forested wetland.

Judgment of Compilers
Among the more important judgments made by the author-compilers was the selection of common points on the source and base maps for scale matching and map registration. Fortunately, a significant number of well-defined manmade features shown on the old maps, such as dikes, railroad lines, and intersections of roads, have persisted to the present; these were the preferred references for comparison and map control. The survival of these historical features was verified by use of intermediate-age maps, color aerial photographs, and spot-checking in the field on such evidence as present condition of the feature and vegetative growth. In addition, distinct topographic features (bluffs, ravines, and rock outcrops) were used as supplement-

SUMMARY AND INTERPRETATIONS

A comparison of the earliest maps of 11 major deltas in the Puget Sound region with modern topographic maps can improve the understanding of dynamic processes of the river-mouth deltas and the impacts of man's activities upon the delta areas. Such a comparison provides documentation of (1) shoreline modifications, both natural and man-induced, since non-Indian settlement, (2) loss or gain of wetlands, and (3) patterns of land-use changes on delta lands.

Dredging, sinking of pilings, and manmade structures along the shoreline constitute changes, however, the influences of these changes are not specifically discussed in the report, and are not always discernible from the maps.

Shoreline Changes
The processes that result in delta-shoreline changes are several and complex and, for the deltas in the Puget Sound region, have not yet been adequately studied. The marine side of the delta environment is especially complex and dynamic, involving wave action, seasonal changes in shoreline erosion and deposition, major tidal fluctuations and currents, and, in some cases, significant transport of sediments by longshore currents. Even if those conditions and processes were well understood with respect to this region, detailed discussion of them here would be inappropriate. However, some understanding of the relationships between the fresh-water and salt-water sides of the deltas—the general principles and processes involved—is necessary for an evaluation of the changes that take place at delta shorelines and, especially, the possible relationships of man's activities to the shoreline changes. Accordingly, the following brief discussions of delta progradation and recession include mention, in very generalized terms, of some of these basic principles and processes.

Progradation

Delta building, or progradation of the delta front, is a natural consequence of sediment-laden stream water discharging into a quieter body of water, such as a marine bay. Progradation takes place where, and so long as, the sediment load exceeds subsidence or the ability of currents and waves within the receiving waters to carry the sediment away from the delta front. Rivers are not the only source of sediment for local delta building; some sediment may be derived from natural erosion of sea cliffs and other segments of the shoreline and moved by estuarine, wind, and tide-generated currents. Because of man's complex intervention with nature, it is often difficult to distinguish between natural and man-caused sediment loads that may influence the occurrence and amount of progradation of a particular delta. However, man's activities commonly affect sediment supply or the path of distributary streams and marine currents in ways that may be reflected in progradation of the deltas. These include:

- (1) Activities that increase sediment supply, such as erosion-producing activities in the drainage basin and along adjacent shorelines, sea cliffs, and other nearby streams that feed the delta. Examples include land clearing and cultivation, logging, mining, and in-stream construction.
- (2) Activities that tend to reduce sediment load, at least for the short term. These include reducing erosion of land or streambanks through revegetation, bank stabilization, and construction of on-shore reservoirs. Sediment-reducing activities tend to retard delta progradation.
- (3) Activities such as stream channelization, channel dredging, mining of coal and materials, and construction of groins, jetties, and breakwaters that affect current flow and sediment erosion-deposition patterns. For example, manmade structures, such as groins and breakwaters, interrupt the movement of sediment, resulting in deposition on the updrift side of the structures and erosion on the downdrift side.

With information about the position of the shoreline at only two specific times—when the early and the modern mapping took place—only the overall change in shoreline can be discerned, and little can be said with confidence about the role that man's activities may have played in a change. Evaluation of artificial influence on shoreline change would require additional data such as shoreline positions at intermediate times, records of average sediment loads over time, and the nature and timing of different types of man's activities. However, some general observations can be made. For deltas that have prograded significantly—the Nooksack, Stillaguamish, and Dungeness deltas—the sediment load has been on the average, greater than the ability of the marine currents and waves to move the sediments from the delta front. Those deltas are most likely, of all the deltas studied, to continue prograding at a relatively rapid rate. The Stillaguamish River, in particular, is susceptible to progradation because of its relatively recent receiving bed, unaffected by strong marine currents, and large intertidal fan serving as an "apron" for subaerial buildup of sediments. Similarly, the progradation of the Nooksack River into the relatively quiet waters of Bellingham Bay may be occurring at a faster rate than would have been the case if the river still flowed into the more exposed, active waters of Lummi Bay. Conversely, for the deltas whose shorelines have had no significant progradation such as the Skagit and Snohomish deltas, the ability of marine currents to move sediment from the delta front has, on balance, been equal to the average sediment load supplied to the delta.

For deltas where artificial filling has occurred far beyond the historical shoreline, such as the Duwamish and Puyallup deltas, little can be said about the natural tendency for, or rates of, progradation; at least unless or until the natural delta-building processes "catch up" with man's artificial extensions of the delta lands. The future resumption of any progradation beyond these artificial fills may be delayed by periodic dredging of sediment from the channels.

Recession

Overall recession or retreat of a delta shoreline results from the sediment discharge of the delta distributaries being less than the transport of sediments from the delta front. Shoreline retreat may be the result of a natural shift of the eroding marine processes or of a reduction in sediment supply by natural or manmade causes, or both. The natural systems tend to adjust to the reduction in available sediment by increasing erosion of unprotected delta land until a state of equilibrium is reached (see subsequent discussion). Therefore, any proposal to cut off sediment supply to a large segment of delta should be carefully considered because the predictable delta response would be a recession of the delta under unbalanced influence of marine processes. As the flow and sediment load of the distributaries change with time, some parts of the delta shoreline may be eroded and retreat at the same time that other parts of the shoreline may be prograding. This apparently has taken place at the Skagit and Nisqually deltas. The slight erosion of the Lummi delta

shoreline probably is related to the reduced discharge of sediment that resulted from the shift of the Nooksack River outlet to the present Nooksack delta. The shoreline of Lummi delta may be somewhat protected from erosion in the future by the dike for a large aquaculture pond completed in 1971.

Shifting of Stream Channels

Periodic shifting of distributary channels is a common characteristic of most deltas and is not necessarily caused by man. As the delta builds beds along one part of its perimeter, the stream eventually breaks out of its channel and takes a shorter, steeper route to another part of the delta front. Distributary patterns also change as a result of lateral diversity of the shoreline and, along with eroding bank materials, major channel shifts often occur during occasional large-scale flooding.

Major stream channel shifts have occurred for the Nooksack, Stillaguamish, and Dungeness rivers. Since the early mapping these rivers have moved from one part of the delta to another. Lateral migration of individual stream channels is particularly noticeable for the Skagit and Nisqually deltas.

Man-caused Shoreline Modifications

Shorelines of river-mouth deltas in the undisturbed state represent an intricate set of processes at the land and water interface. Near the river mouth, shorelines include sand bars, islands, tidal creeks, and sloughs. In these areas fish and other estuarine and wetland inhabitants have available a variety of streambank, streambed, and vegetative environments that provide abundant food and shelter. Shoreline modifications, especially by diking and channelizing of streams, alter the natural diversity of the shoreline and, along with conversion of wetland to other land uses, reduce the habitat available for aquatic life.

Diking and filling near the distributary channels or the seaward shore of the delta has occurred at most of the deltas studied. In general, the fill for dikes or levees along the distributary channels has been placed closer to the edge of the water than the fill for dikes along the delta seashores. The most extensive modifications of shoreline have occurred on the Duwamish and Puyallup deltas by both dredge-and-fill and stream-channelization projects. In the Duwamish delta the meandering river has been reduced to about one-half of its former length by channel straightening. Most of the present shoreline of the Duwamish and Puyallup deltas is landfill protected by bulkheads. The shorelines of the Snohomish delta have been altered by landfilling, but to a much lesser extent than the Duwamish and Puyallup deltas.

Development on Delta Deposits

In the Puget Sound region, river-mouth deltas are prized as residential, commercial, and industrial tracts because they provide large areas of flat-lying land close to water. The principal cities along Puget Sound are at the mouths of major rivers—Tacoma (Puyallup River), Seattle (Duwamish River), and Everett (Snohomish River). Natural deltaic sediments consist largely of sand, silt, and gravel. These geologic materials and manmade fill have differing physical characteristics that may directly affect land use. Areas of poorly compacted manmade fill or saturated silt, clay, and organic mud may provide poor foundations for heavy structures. Land overlying part of a sanitary landfill of the Tacoma industrial area has reportedly settled, causing structural problems in buildings. Saturated silt and sand deposits and uncompacted manmade fill also may settle or become unstable during seismic shaking. For example, hydraulic fill that was used to create the industrial area along the Duwamish River subsided during the 1950 and 1965 earthquakes, apparently as a result of liquefaction (U.S. Geological Survey, 1975, p. 95, 99).

In wetland areas, pollution from landfills and other waste-disposal facilities are a potential problem because these areas are frequently subject to periodic flooding and a high water table. For example, the salt-water disposal site at the mouth of the Snohomish River has an on-bank impact on nearby wetlands. The solid waste being deposited on the fill is in direct contact with, or just above, the surface water, making for easy access of leachate into the stream and adjacent estuarine waters.

Loss of Wetland

Subaerial wetland
Coastal wetlands, generally grading from salt-water to fresh-water marsh, are well-known as critically important habitat for fish and wildlife. Sloughs dissecting the marshes attract an abundance and diversity of life and are nursery areas for young fish. Wetland areas are essential for nesting, wintering, and feeding of waterfowl and shore birds. They also help stabilize shorelines, reduce erosion, and buffer the force of storms and floods.

A comparison of present-day and historical wetland areas for each of the deltas is shown in table 2. Eight of the 11 deltas show a loss of subaerial wetland; three deltas show a significant wetland loss of 5 sq km (1.9 sq mi) or more. Diking was an early activity of settlers in the region and accounts for the greatest loss of former wetland. Dikes stopped the tidal flow of salt water into areas previously enclosed permitting the gradual freshening of the soil water and the loss of the subaerial wetland. The loss of wetland was also the result of introduction of plant species suitable for subsequent agriculture. The forested wetland of the Nooksack delta has not been diked at the lower reaches and has about the same amount of wetland as in 1887-88 (table 2). The Lummi and Samish deltas are fed by small river systems and generally have only a narrow fringe of marsh seaward of the dikes near the delta shore. The Skagit delta also has a fringe of marsh seaward of the dikes in the northern part of the delta but a much larger area of wetland (including some forested wetland) along the South Fork distributaries. The Stillaguamish delta, because of its prograding nature, has gained some subaerial wetland since the early mapping in 1886. U.S. Geological Survey Professional Paper 964, 28 p.

The Smithsonian delta has residual "pockets" of wetlands, mostly in its northern part; it originally had the largest wetland area of the deltas studied (table 2). The Duwamish and Puyallup deltas have been most extensively developed and have little or no remaining wetland. The Nisqually and Skokomish deltas have been partly diked and have much remaining undisturbed wetland. For the Dungeness delta, although natural changes have occurred, the net loss or gain of wetland from former conditions does not appear to be significant. Of the 11 river-mouth deltas studied, about 55 sq km (21 sq mi) of subaerial wetland have been converted to other land uses from an estimated 91 sq km (35 sq mi) mapped during the historical surveys.

Intertidal Wetland

Tidelands and submerged grass beds are critical habitat for aquatic life. The plant production from these areas becomes available as organic detritus which provides the chief food for the coastal fish and shellfish populations of

TABLE 1.—Source maps for compilations of historical shorelines.

Field sheet	Name	Year surveyed	Agency	Topographer	Original scale
T-539	New Dungeness—Strait of Juan de Fuca	1855	Coast Survey	J. L. Lawson	1:10,000
T-1463	Commencement Bay—Puget Sound	1877	Coast Survey	Eugene Elliott	1:10,000
T-1560b	Hood Canal—Annes Bay	1884	C&GS	J. J. Gilbert	1:10,000
T-1672	Puget Sound from Nisqually River to Totem Inlet	1878	Coast Survey	Eugene Elliott	1:20,000
T-1681	Snohomish River	1884-85	C&GS	J. F. Pratt	1:20,000
T-1755	Port Susan and Stillaguamish River	1886	C&GS	J. F. Pratt	1:20,000
T-1794	Rosario Strait—Guemes, Samish, Vendo Islands	1887	C&GS	J. J. Gilbert	1:10,000
T-1795	Rosario—Samish Bay	1887	C&GS	J. J. Gilbert	1:10,000
T-1798	Rosario Strait—North Port of Bellingham Bay	1887	C&GS	J. J. Gilbert	1:10,000
T-1799	Rosario Strait—Nooksack River	1887	C&GS	J. J. Gilbert	1:10,000
T-1871	Gulf of Georgia—Village Point to base of Sandy Point	1888	C&GS	J. J. Gilbert	1:10,000
T-2156	Skagit Bay, Delta and River-Washington	1889	C&GS	J. F. Pratt	1:20,000
T-2421	Seattle Bay and City-Washington	1899	C&GS	J. J. Gilbert	1:10,000
T-2422	Seattle Bay and City-Washington	1899	C&GS	J. J. Gilbert	1:10,000
H-432	Preliminary Survey of Duwamish Bay	1854	Coast Survey	James Alden	1:10,000
H-1728	"Mouth of Snohomish River, copied in part from original hydrographic sheet, H-1728"	1886	C&GS	C. T. Fosse	1:20,000
25-26	Seattle quadrangle	1908	USGS ²	R. H. McKee	1:62,500
	Duwamish-Puyallup Surveys	1907	USCE ³		1:4800
	Plan of Seattle	1855-56		Thomas Phelps	1:2300

¹U.S. Coast and Geodetic Survey.
²U.S. Geological Survey.
³U.S. Army Corp of Engineers.

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TABLE 2.—Comparison of historical and present-day subaerial wetland areas.

River delta	Historical	Present-day	Increase or (decrease)	Source
Nooksack	4.5	4.6	0.1	Topographic maps and aerial photographs
Lummi	5.8	.3	(5.5)	Topographic maps
Samish	1.9 (11) ^a	.4	(1.5)	Do.
Skagit	16 (29) ^a	12	(4)	Do.
Stillaguamish	3.0 (10) ^a	3.6	0.6	Do.
Snohomish	39	10	(29)	Topographic maps and aerial photographs
Duwamish	2.6	.03	(2.6)	Topographic maps
Puyallup	10	virtually none	(10)	Do.
Nisqually	5.7	4.1 ^b	(1.6)	Do.
Skokomish	2.1	1.4	(0.7)	Topographic maps and aerial photographs
Dungeness	.5	.5	0	Do.
Totals for mapped areas	91	37	(55)	

^aNumber in parentheses is an estimate based on vegetation and locations of wetland area present prior to its conversion and before the final C&GS topographic survey under natural conditions.
^bIncludes about 1.6 sq km that were wet meadow and fresh-water marsh landward of present dikes prior to December 1975 (dike break (Pike) and others, 1978), in addition to about 2.5 sq km of salt marsh.

TABLE 3.—Comparison of historical and present-day intertidal wetland areas.

River delta	Historical	Present-day ^a	Increase or (decrease)	Remarks
Nooksack	6.7	8.5 ^b	1.8	Intertidal area measured from lat 48°45'00", near Fish Point, to long 122°32'30".
Lummi	14	13	(1.0)	Intertidal area measured from long 122°42'30", near Sandy Point, to lat 48°45'00", near Casey Road.
Samish	not available	15	?	Present-day intertidal area measured from long 122°30'00" near Fish Point, to lat 48°37'30" near Pigeon Point.
Skagit	Do.	55	?	Present-day intertidal area measured from lat 48°15'12", Brower Point, to lat 48°24'24", near Deadman Island (off map).
Stillaguamish	Do.	20	?	Present-day intertidal area measured from long 122°27'30", near Lona Beach, to lat 48°10'00", near Warm Beach.
Snohomish	13 ^c	8.8	(4.2)	Present-day intertidal area measured from lat 48°02'48", near Mission Bay (off map), to lat 47°59'00", near Port Gardner.
Duwamish	8.5	virtually none	(8.5)	Historical intertidal area measured from long 122°23'00", Duwamish Head, counter-dock-west around Elliott Bay, to long 122°23'30", near Smith Cove.
Puyallup	7.4	0.1	(7.3)	Historical intertidal area measured from lat 47°15'48", near City Waterway, to lat 47°17'12", near Hyabusa Waterway.
Nisqually	7.4	5.8	(1.6)	Intertidal area measured from long 122°45'00", near Wolf Blight, to long 122°40'00", near Sequelchew Creek.
Skokomish	5.0	4.5	(0.5)	Intertidal area measured from lat 47°21'36", near Lona Beach, to lat 47°21'36", near Lona Beach.
Dungeness	5.9	6.0	0.1	Intertidal area measured from lat 48°11'00", near Dungeness Lighthouse, counter-dock-west around Dungeness Bay, to long 122°05'00", near Junction.

^aFrom U.S. Geological Survey topographic maps, except Nooksack River delta (see below).

^bFrom NOAA hydrographic survey, H-8323, H-8321 (1:10,000 scale) dated 1956.

^cHistorical intertidal area is based on 1886 hydrographic chart that maps lower low-water line in not entirely shown on sheet 5 because sheet map does not extend far enough in seaward direction.

commercial importance. Natural, unspoiled mud flats teem with animal life that includes snails, mussels, and oysters, as well as a variety of crabs, shrimp, and small fishes.

A comparison of present-day and historical intertidal areas for eight of the eleven deltas is shown in table 3. The intertidal area of the Lummi, Skokomish, and Dungeness deltas has remained about the same since the early mapping. Extensive dredge-and-fill projects carried out on the Duwamish and Puyallup deltas have eliminated about 16 sq km (6 sq mi) of intertidal habitat. In the Snohomish delta, dredge-and-fill operations have eliminated about 2.6 sq km (1.0 sq mi) of intertidal area from an estimated overall loss of 4.2 sq km (1.6 sq mi) of intertidal wetland based on comparison of historical and present-day maps (table 3).

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